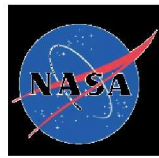


AeroMACS C-Band Interference Modeling and Simulation Results

Jeffrey D. Wilson

Summary

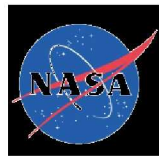
A new C-band (5091–5150 MHz) airport communications system designated as Aeronautical Mobile Airport Communications System (AeroMACS) is being planned under the Federal Aviation Administration's NextGen program. It is necessary to establish practical limits on AeroMACS transmission power from airports so that the threshold of interference into the Mobile Satellite Service (Globalstar) feeder uplinks is not exceeded. To help provide guidelines for these limits, interference models have been created with the commercial software Visualyse Professional. In this presentation, simulation results were shown for the aggregate interference power at low earth orbit from AeroMACS transmitters at each of up to 757 airports in the United States, Canada, Mexico, and the surrounding area. Both omni-directional and sectoral antenna configurations were modeled. Effects of antenna height, beamwidth, and tilt were presented.



AeroMACS C-Band Interference Modeling and Simulation Results

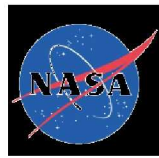
Jeffrey Wilson
NASA Glenn Research Center

Presented by James Budinger
Joint Meeting of RTCA SC-223 and EUROCAE WG-82
Brussels Belgium
28-30 September 2010



Introduction

- AeroMACS transmit power limitations need to be determined in order to prevent interference from AeroMACS into other existing systems.
- Issue of immediate interest is interference from AeroMACS into the Mobile Satellite Service (Globalstar) feeder uplinks (5091-5150 MHz).
- This effort will focus on establishing practical limits on AeroMACS transmissions from airports so that the threshold of interference into Globalstar uplink at low earth orbit (LEO) is not exceeded.
- Utilizing Visualyse Professional Version 7 software from Transfinite Systems Limited (UK).



Visualyse Modeling Procedure

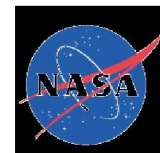
1. Define antennas.
2. Locate stations.
3. Specify carriers.
4. Set up propagation environment.
5. Set up links.
6. Set up interference paths.
7. Specify output desired.
8. Run.
9. Analyze results.



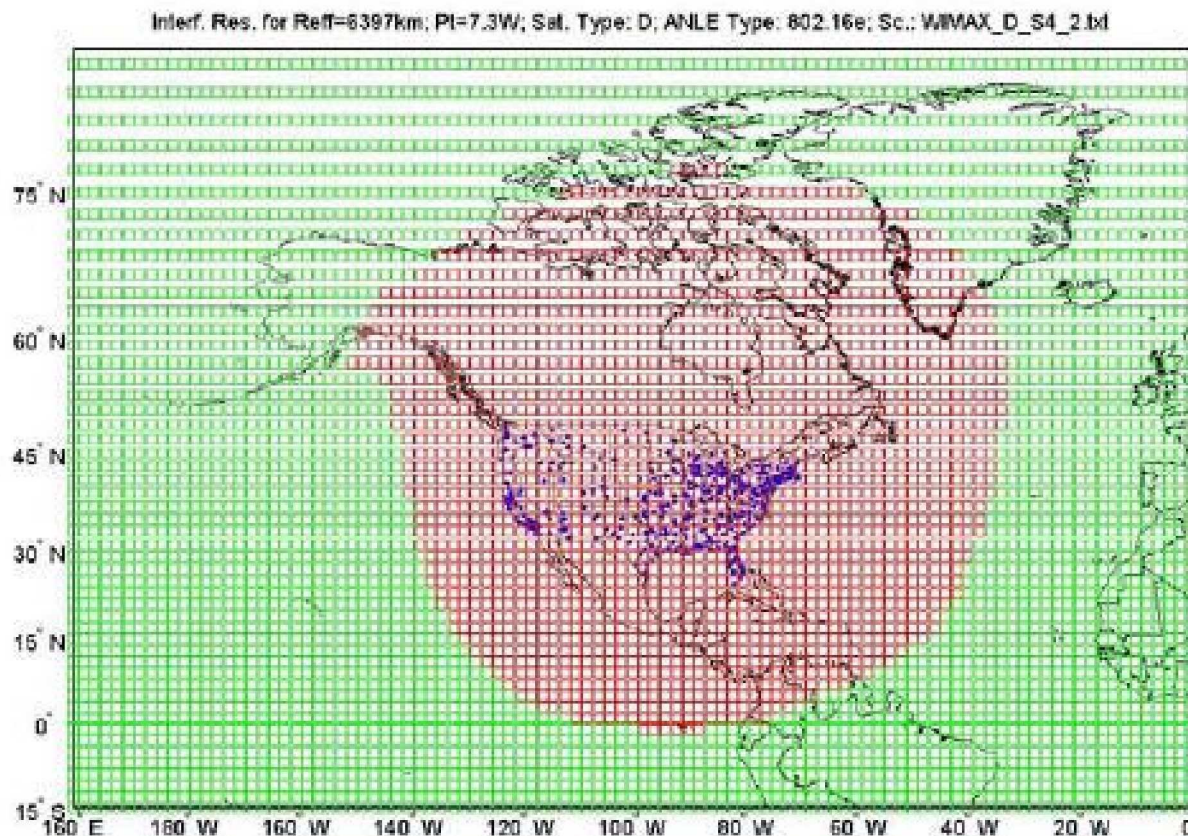
Benchmark Case

Reference: Hoh, Gheorghisor, and Box, Feasibility Analysis of 5091-5150 MHz Band Sharing by ANLE and MSS Feeder Links, MITRE-CAASD Report MP 05W0000083, 2005.

- ☐ Investigated co-channel interference from ANLE (Airport Network and Location Equipment / now referred to as AeroMACS) system to mobile-satellite-service (MSS) feeder uplinks.
- ☐ Assumed one transmitter with omni-directional antenna at each of 497 major airports in contiguous United States.
- ☐ Worst case scenario: all transmitters on 100% of time.
- ☐ Transmitted power from each airport = 5.8 watts.
- ☐ Calculated aggregate interference power at Low Earth Orbit.

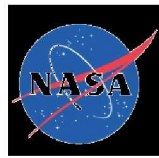


Benchmark Results (from Hoh, et al.)



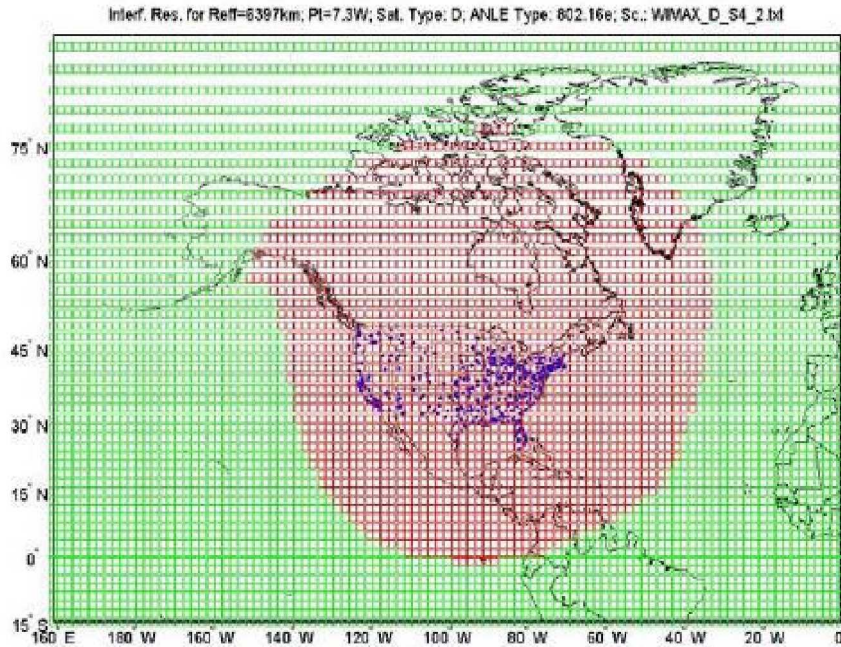
- Aggregate interference power at LEO (1414 km) from 497 airports.
- Threshold (- 155.5 dBW) exceeded in red area*.

*Note threshold definition has since been tightened to -157.3 dBW corresponding to 2% increase of satellite receiver's noise temperature.



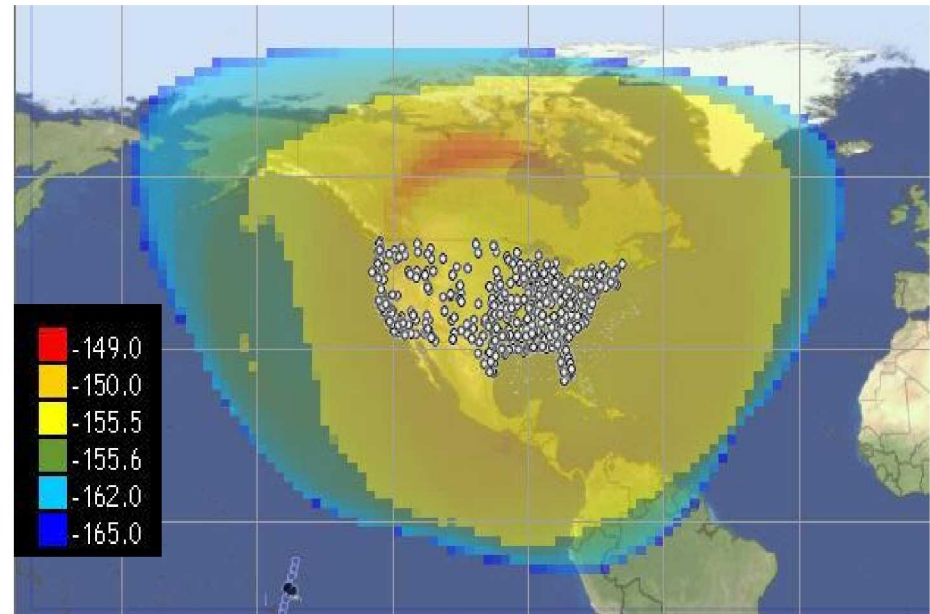
Visualyse Results Comparison

Hoh, et al.:



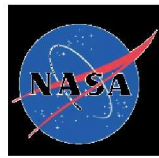
- Red/green border = -155.5 dBW
- Max interference = -150.0 dBW
- Max location = 67°N 104°W

Visualyse:



- Yellow/green border = -155.5 dBW
- Max interference = -149.3 dBW
- Max location = 64°N 105°W

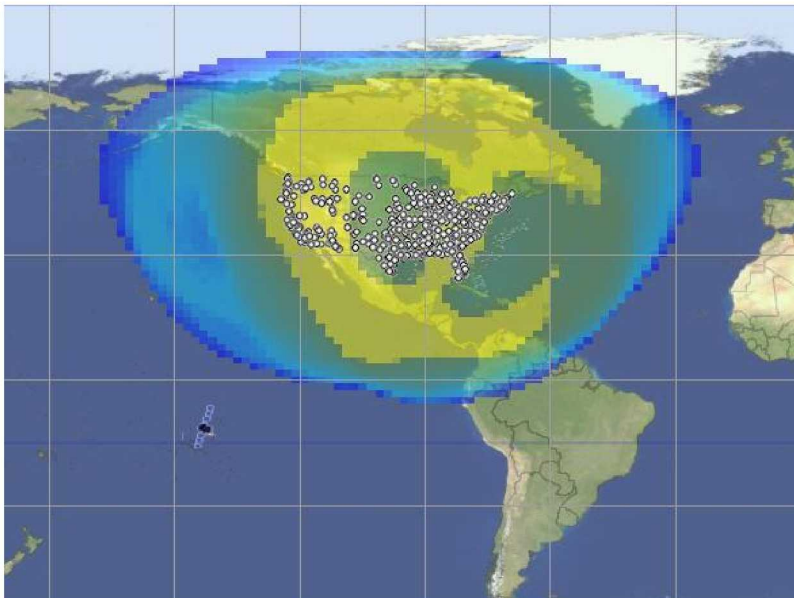
Excellent agreement between Visualyse and MITRE results.



Interference Power, 20 MHz Channel

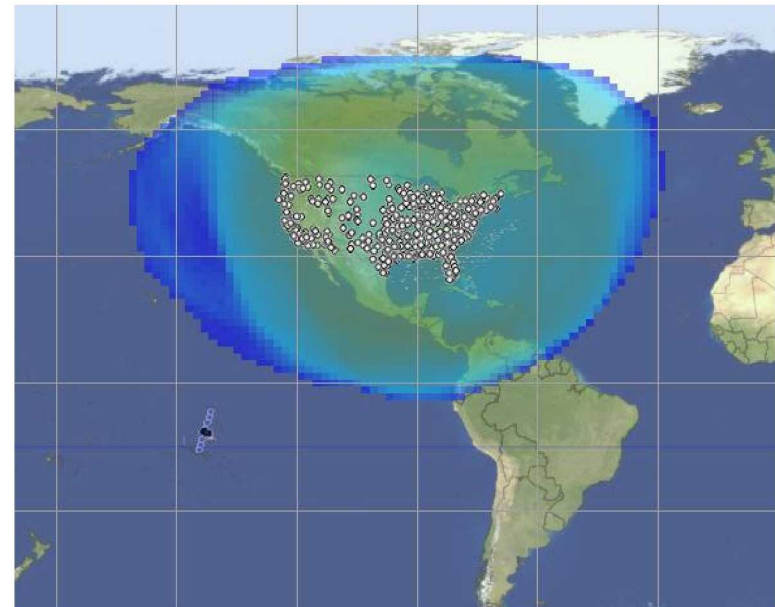
- ☐ Decrease transmitted power until interference power under threshold.
- ☐ Yellow/green border = -157.3 dBW .

1440 mW:

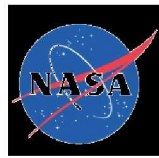


Below threshold in U. S. Midwest

891 mW:

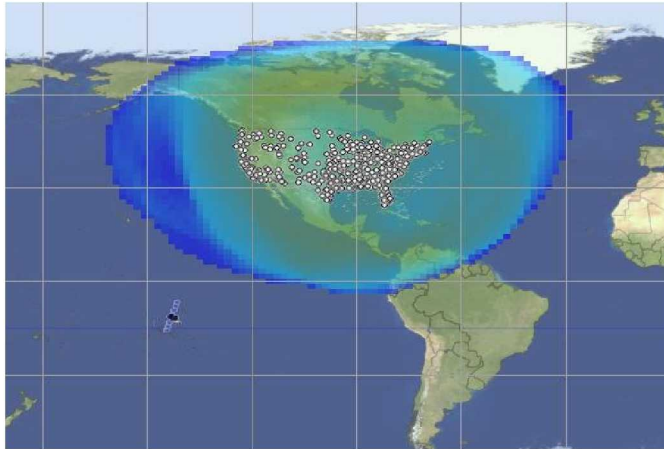


Below threshold everywhere



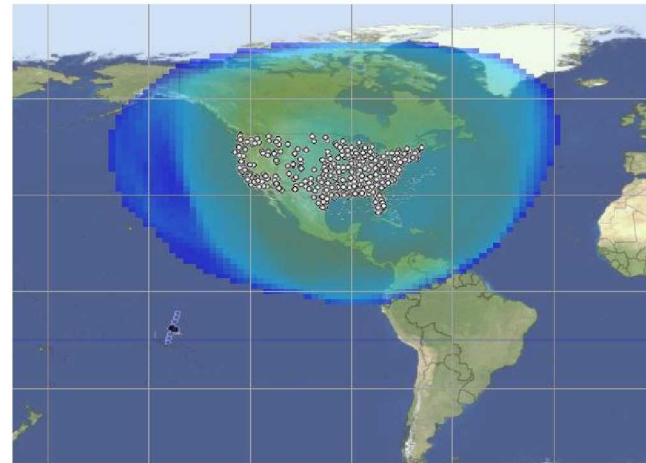
Interference Power, 10- and 5-MHz Channels

10 MHz Channels:



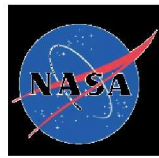
447 mW

5 MHz Channels:

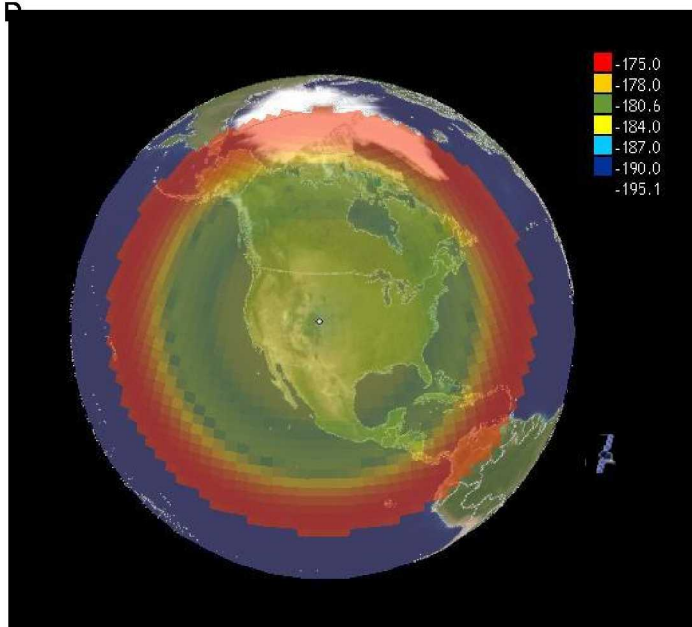


224 mW

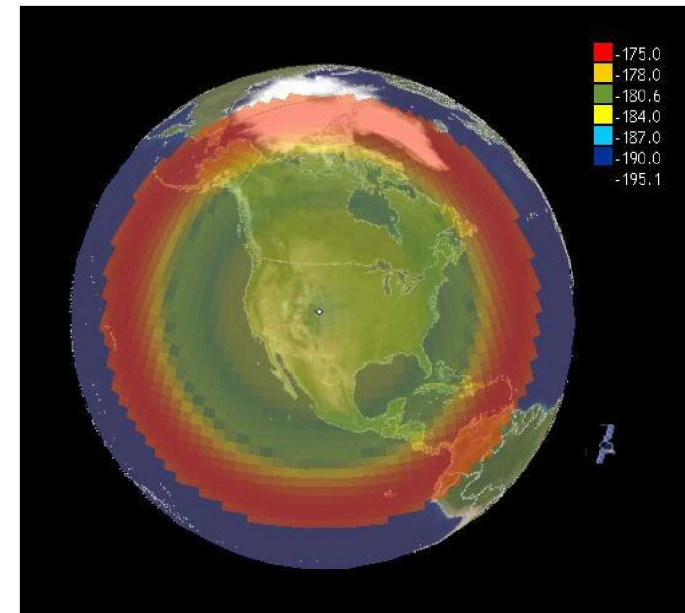
- ❑ Maximum transmitted power proportional to channel bandwidth.
- ❑ Thus for 5-MHz channels, the transmitted power at each airport needs to be decreased to 224 mW to keep interference power below -157.3 dBW everywhere.
- ❑ Interference hot spot in NW Territories of northern Canada.



Interference Power for Single Airport Model

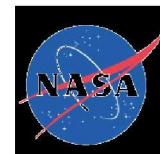


Denver (sea level)

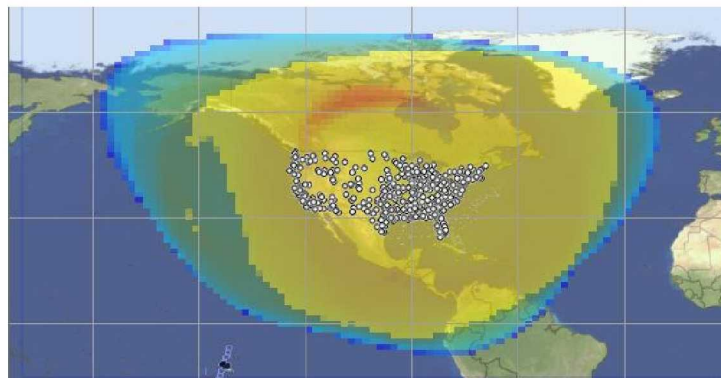


Denver (5431 feet)

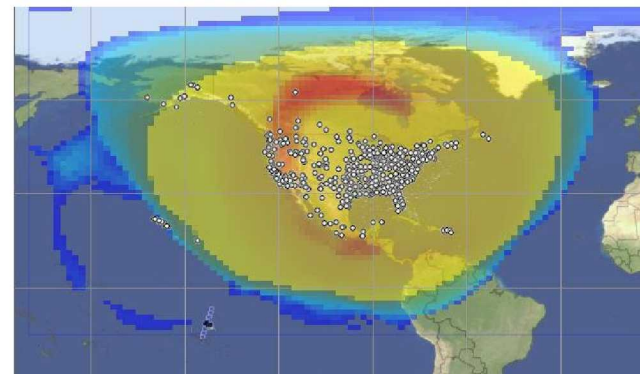
- Max interference power -175.5 dBW in both cases.
- Antenna elevation (1.6 km) has minimal impact on interference power at Low Earth Orbit (1414 km).



Effect of Additional Airports



497 Airports



757 Airports

- ❑ 497 Airport Model includes just major contiguous US airports.
- ❑ 757 Airport Model includes all 703 FAA towered airports and heliports, adding Alaska, Hawaii, and Caribbean, plus 34 Canadian and 20 Mexican airports.
- ❑ To remain under threshold (-157.3 dBW) for 5-MHz channels:
 - ± 497 airports - 224 mW transmission per airport max.
 - ± 757 airports - 201 mW transmission per airport max.
- ❑ Maximum allowable transmission per airport decreases only 10% from increasing number of airports by 50%.

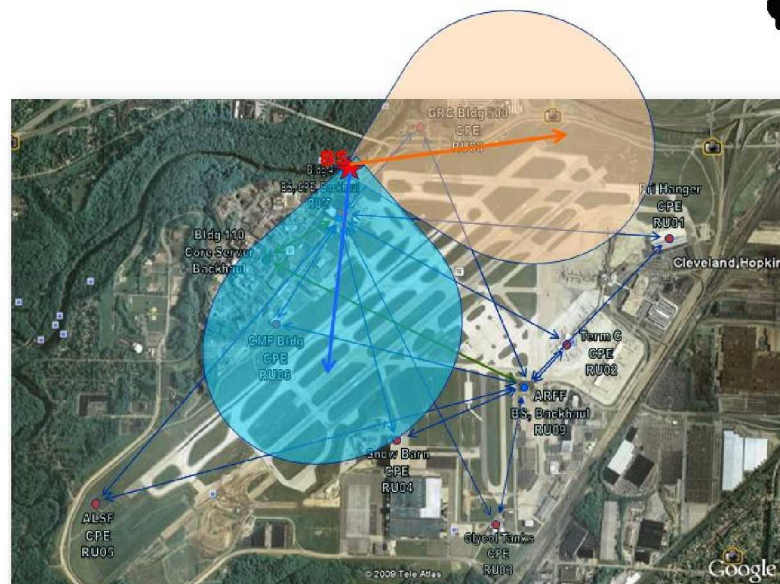


Sectoral Antenna Configurations

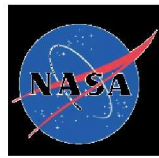
- Previous simulations with omni-directional antennas.
- Sectoral antennas can provide more targeted coverage.
- Consider configurations with one, two, and three transmitters/beams randomly directed at each of 757 airports.
- In two- and three-beam configurations, beams separated by 120° at each of 757 airports.



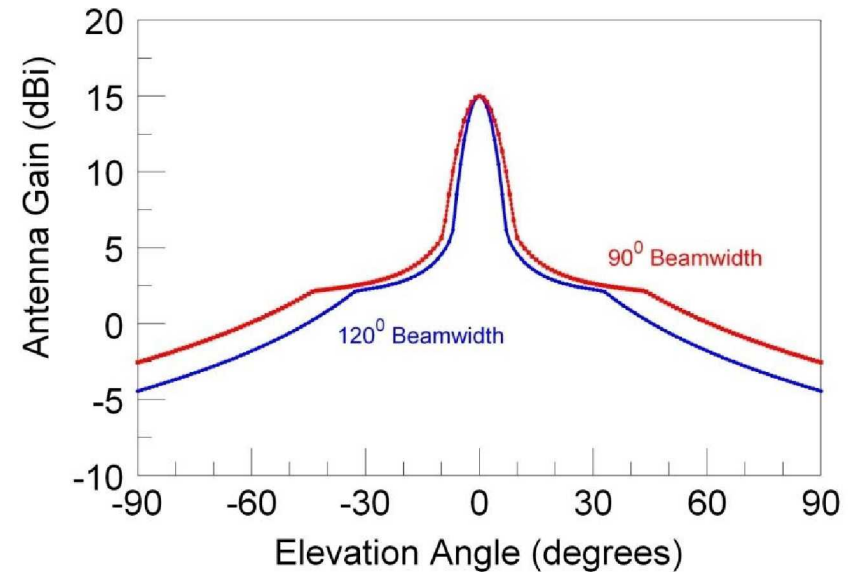
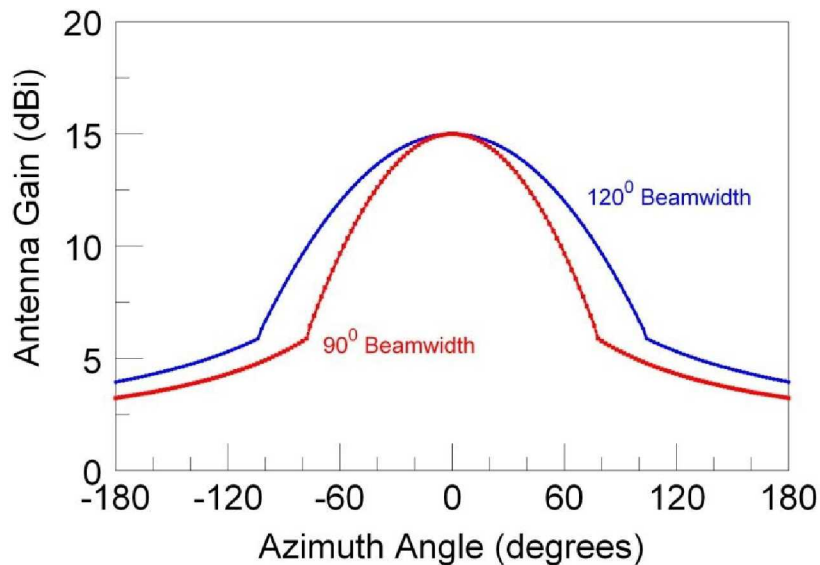
One-beam example



Two-beam example



Sectoral Antenna Beamwidths

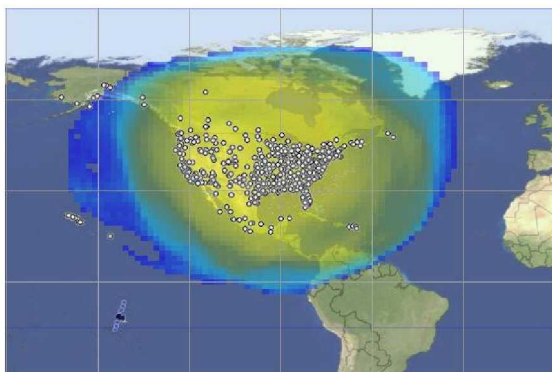


- For each configuration considered both 90° and 120° beamwidth sectoral antennas.
- Maximum gain = 15 dBi.
- 90° beamwidth gain is narrower in azimuth, but broader in elevation \pm thus more radiation in upward direction.



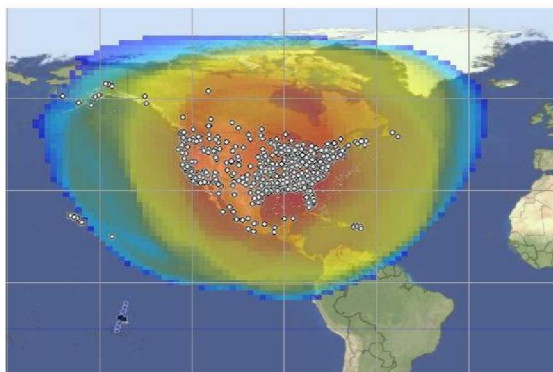
Sectoral Antenna Interference Power

- Each beam transmits -8.7 dBW (135 mW).
- Resulting interference power for 90° beamwidth:



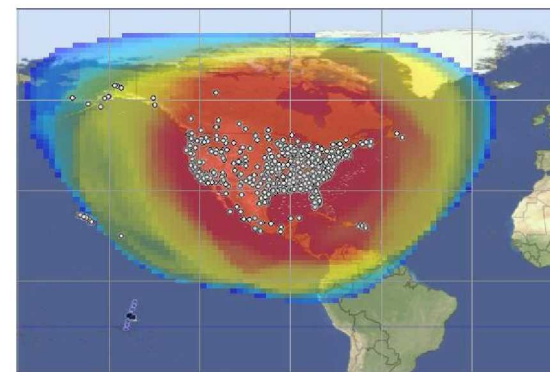
1 Beam per Airport

$P_{\max} = -160.5$ dBW
latitude = 35°
longitude = -79°
(Fayetteville, NC)



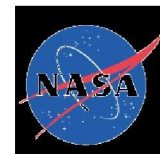
2 Beams per Airport

$P_{\max} = -157.5$ dBW
latitude = 30°
longitude = -77°
(150 km E of Jacksonville, FL)



3 Beams per Airport

$P_{\max} = -155.8$ dBW
latitude = 35°
longitude = -79°



Threshold Transmitted Power

- Maximum transmitted power per beam to remain under -157.3 dBW threshold everywhere with 5 MHz channels (double these values for 10 MHz channels):

	1 Beam	2 Beams	3 Beams
90° Beamwidth	141.8 mW	70.4 mW	47.4 mW
120° Beamwidth	166.0 mW	83.2 mW	55.3 mW

Total allowable transmitted power per airport approximately independent of number of beams.

Transmitted power can increase by 17% if beamwidth increased from 90° to 120° (less upward propagation).

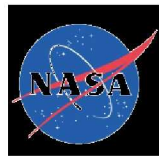


Antenna Tilt Effects

- Modeled antennas with downward tilt to reduce upward propagation.
- 3 Beam configuration.
- Maximum transmitted power per beam (mW) to remain under -157.3 dBW threshold everywhere with 5 MHz channels:

tilt	0 ⁰	-1 ⁰	-2 ⁰	-3 ⁰	-4 ⁰
90 ⁰ BW	47.4	48.9	50.0	50.5	51.0
120 ⁰ BW	55.3	60.4	63.9	67.0	68.1

- Benefit from downward tilt significantly stronger for 120⁰ beamwidth.
- For example with -2⁰ tilt, allowable transmitted power increases by only 5.5% for 90⁰ beamwidth, but by 15.5% for 120⁰ beamwidth.



Future Plans

- ☐ Improve model realism for single airport
 - ± Multiple base and subscriber stations
 - ± Transient effects
 - ± Terrain and building effects
 - ± Multipath signal propagation effects

- ☐ Adjacent band interference from AeroMACS

- ☐ Co-channel and adjacent band interference into AeroMACS

- ☐ Geographically close AeroMACS implementations



Conclusions

- ❑ Modeled C-band aggregate interference power at LEO from 497 and 757 airport models with Visualyse software.
- ❑ Benchmark results agree very well with MITRE-CAASD.
- ❑ Antenna elevation has minimal impact on interference power at LEO.
- ❑ Increasing number of airports by 50% (from 497 to 757) has only 10% impact on threshold transmitted power.
- ❑ Total allowable transmitted power per airport approximately independent of number of beams.
- ❑ Transmitted power can increase by 17% if beamwidth increased from 90° to 120°.
- ❑ Downward tilt of antennas is almost three times as beneficial for 120° beamwidth sectors as compared to 90° sectors.